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TRANSLATOR'S DECLARATION

I, Walter F. Fasse, having an office at: 60G Main Road North,  
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solemnly declare:

that I am fully conversant and knowledgeable in the German language to fluently read, write, and speak it, I am also fully conversant and knowledgeable in the English language;

that I have, to the best of my ability, prepared the attached accurate, complete and literal translation of:

PCT International Application PCT/DE2004/001426, filed on July 3, 2004

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: January 9, 2006



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ACCURATE LITERAL TRANSLATION OF PCT INTERNATIONAL APPLICATION  
PCT/DE2004/001426 AS FILED ON 3 JULY 2004

# Milling Method for the Production of Components

The invention relates to a milling method for the production of structural components according to the preamble of the patent claim 1.

5 The present invention relates to the field of milling technology, especially the HSC milling (High Speed Cutting milling), which is also designated as HPC milling (High Performance Cutting milling).

10 In the milling of a workpiece for the production of a structural component, it is of decisive significance, that the miller or the milling tool, during the milling, does not damage the geometry or freeform surface of the structural component that is to be milled. If, for example, the structural component to be milled is a rotor with integral blading, whereby for such a rotor, flow  
15 channels are to be milled-out between neighboring blades with the aid of the milling method, then the miller or the milling tool, during the milling-out of a flow channel, may not damage the blades bounding the flow channel or the corresponding blade surfaces thereof. Accordingly, a collision of the miller with  
20 the blades or blade surfaces must be surely prevented. This is especially significant when the tool paths or the tool vectors

are defined through the use of cutting advance or lead angles and clearance or pitch angles.

Starting from this point, the underlying problem on which the present invention is based, is to propose a novel milling method for the production of structural components.

This problem is solved in that the above initially mentioned milling method is further developed by the features of the characterizing part of the patent claim 1.

According to the invention, at least one collision contour is defined in addition to the or each tool path, whereby the position or orientation of the milling tool relative to the or each collision contour is monitored, and whereby the position or orientation of the milling tool is changed and/or an error message is generated if at least one of the collision contours is damaged by the milling tool. With the present invention, an especially effective method is proposed, in order to surely avoid a collision of the miller with surfaces of the structural component to be produced.

According to an advantageous embodiment of the invention, for the milling of depressions or recesses that are bounded by two sidewalls, two collision contours are defined, whereby a first collision contour corresponds to a first sidewall and a second collision contour corresponds to a second sidewall. In the case in which the milling tool damages the collision contour that

corresponds to the first sidewall that is currently to be milled, the position or orientation of the milling tool is changed in such a manner that the damage of the collision contour is removed. In the case in which the milling tool damages the collision contour that corresponds to the second sidewall, which lies opposite the first sidewall that is currently to be milled, an error protocol and/or an error message is generated.

Preferred further embodiments of the invention arise from the dependant claims and from the following description.

An example embodiment of the invention, without being limited hereto, is explained in further detail in connection with the drawing. In the drawing:

Fig. 1 shows a strongly schematized cross-section through a rotor with integral blading and with a miller in two different positions for clearly explaining the method according to the invention; and

Fig. 2 shows a strongly schematized cross-section through a rotor with integral blading and with a miller in two further different positions.

In the following, the present invention will be explained in greater detail with reference to the figures. Before the details of the inventive method will be explained, however, in the

following a few terms will be defined, to which reference will be made later.

The milling machining or processing of the workpiece or material to be machined is achieved with the aid of a tool, a so-called miller. During the milling, the miller is in engagement with the material. For the processing or machining of the workpiece, the tool or the miller is moved relative to the workpiece or the material. The motion of the tool or the miller relative to the workpiece is described by so-called tool coordinates, whereby the tool coordinates define the position of a tool reference point. The motion of the tool reference point in the milling machining of the workpiece is designated as the tool path or milling path.

Beginning from a tool tip or from the tool reference point, a vector extends along a tool axis or a tool shaft of the tool or miller. This vector along the tool axis beginning from the tool tip in the direction of the tool shaft is referred to as a tool vector.

The milling machining or processing of a workpiece for the formation of a defined three-dimensional freeform surface takes place with the aid of a so-called 5-axis milling. In the 5-axis milling, the tool can be moved in five axes relative to the workpiece that is to be machined. Three axes serve for the linear relative motion of the tool relative to the workpiece, so that each point in space can be reached. In addition to this linear motion along the so-called linear axes, the tool is also

movable about a pivot axis as well as a tilt axis for the realization of undercuts. Rotational motions of the tool are made possible along the pivot axis as well as the tilt axis. Hereby it is possible, that all points in space can be reached without collision. The pivot axis as well as the tilt axis are often generally also designated as round or circular axes.

In the following, the invention will be explained in greater detail with reference to Figs. 1 and 2. Figs. 1 and 2 show, in a strongly schematized manner, a rotor 10 with integral blading, whereby respectively two rotor blades 11, 12 are shown in Figs. 1 and 2. A flow channel 13 is enclosed between the rotor blades 11, 12. The inventive milling method now serves for the production of such a rotor 10, whereby through the use of a milling tool or miller, the flow channel 13 is to be milled-out in such a manner, so that the desired contour of the rotor blades 11, 12 arises. It is pointed out once again that the illustration in Figs. 1 and 2 is strongly schematized. The shape and dimensioning of the rotor blades 11, 12 as well as the shape and dimensioning of the flow channel 13 bounded by the rotor blades 11, 12 was selected solely for reasons of a simple illustration, and is of subordinate significance for the principle of the present invention.

In Figs. 1 and 2, a milling tool 14 is respectively shown in two different positions. A first position of the milling tool 14 is respectively carried out in continuous solid lines and corresponds to a position or orientation of the milling tool 14

in which the milling tool 14 does not damage the contour of the rotor blades 11 and 12. In this position or orientation of the milling tool, accordingly there is no collision with the structural component or rotor 10 that is to be produced. In a second position or orientation of the milling tool 14, which is shown with dashed lines in Figs. 1 and 2, the milling tool intersects or cuts the contour of the rotor blades 11 or 12, and thus collides with the structural component geometry that is to be produced. Such a collision must be avoided.

For this purpose, in the sense of the inventive method, at least one collision contour is defined in addition to the or each tool path along which the milling tool is moved during the milling machining. The position or orientation of the milling tool relative to the or each collision contour is monitored. The position or orientation of the milling tool is changed if at least one of the collision contours is damaged by the milling tool. Furthermore it is in the sense of the invention to generate an error message or an error protocol, if at least one of the collision contours is damaged. The producing or generating of the error message or the error protocol can also be carried out instead of the changing of the miller position.

As can be understood from Figs. 1 and 2, in principle two types of collisions of the milling tool 14 with the rotor blades 11, 12 are conceivable during the milling of the flow channel 13. In the possibility shown in Fig. 1, the rotor blade 12 that bounds the flow channel 13 on the right side is milled-out with

the milling tool 14. With a too-sharp tilt of the milling tool 14, a collision can arise with the other rotor blade 11, which lies opposite the rotor blade 12 that is being machined by the milling tool 14. On the other hand, Fig. 2 visualizes a collision of the milling tool 14 with the rotor blade 11 that is currently being machined by the milling tool 14. Both collision types are covered by the inventive milling method.

The collision contours that are to be defined and that may not be damaged by the milling tool 14 correspond to the surfaces or the edges of the rotor blades 11 and 12 that are to be milled-out. These can be defined in that the milling tool is moved with its tip along the edges of the rotor blades that are to be milled-out, and all motions that are carried out along these edges are defined as collision contours. Thus, the collision contours always refer to the structural component that is to be produced, and define an area or region that the milling tool 14 may not damage, neither with its shaft nor with its radius.

In the case in which the milling tool 14 damages the collision contour that corresponds to the sidewall that is currently to be milled (see Fig. 2), the position or orientation of the milling tool 14 is changed in such a manner so that the damage of this collision contour is removed. For this purpose, the clearance or pitch angle of the tool vector is increased so far that a collision-free motion of the milling tool 14 becomes possible.



In the case in which the milling tool 14 damages the collision contour that corresponds to the sidewall that lies opposite to the sidewall that is currently to be milled (see Fig. 1), according to the invention an error message or an error protocol is generated. In this case the clearance or pitch angle of the miller is not changed.

If, during the above method, it is determined that the miller or the milling tool 14 cannot be moved without collision through the flow channel 13, which is bounded by the collision contours, then according to the invention the miller radius or miller diameter of the milling tool is adapted. The miller diameter must then be reduced so far that a collision-free production of the structural component is possible. Alternatively it is also possible to adapt the cutting advance or lead angles, so that a collision-free production of the structural component is possible with changed cutting advance or lead angles.

With the aid of the present invention, a milling method is proposed, in which the tool paths or the tool vectors are defined by prescribing cutting advance or lead angles and clearance or pitch angles, and whereby simultaneously a collision of the miller with the surfaces of the structural component to be produced can be surely avoided. Thereby the milling machining or processing of structural components is improved overall. The inventive method can be applied especially advantageously in connection with 5-axis milling.

The inventive milling method can especially be utilized or applied for the production of integral bladed rotors for gas turbines, so-called blades disks (blisks) or bladed rings (blings).